Programmable active matter for transport optimization

Phd position: Matthieu Labousse (Gulliver ESPCI Paris, Supervisor), Emmanuel Fort (Institut Langevin , ESPCI Paris, co-supervisor)

Subject:

Future micro-surgeons in aortic flows, robotic assistance or drone sea rescue under degraded conditions will lead to new applications but will also face fundamental limits: their surrounding flow perturbations usually significantly surpasses their self-propulsive forces. This represents a major problem for realizing their full potential.

Surprisingly a school of fishes or a flock of birds is often more robust to violent external perturbations than isolated individuals. It originates from their local interactions and leads to an emerging collective robustness. As a collective object, they form an ordered and cohesive structure which collectively processes the external perturbations. The development of robotic swarms is a burgeoning field which is rapidly growing. From a theoretical perspective, the modularity and programmability of the interactions between robots is fascinating and paves the way to self-learning collective phases. The interactions could be tuned autonomously and dynamically to optimize the transport properties in a noisy or disordered environment.

The goal of this PhD project is to explore numerically the properties of programmable active matter for transport optimization in degraded situations.

Part I, passive swarms. We will implement numerical swarms of self-propelled particle with passive interactions. For a fixed interaction potential, the self-propelled objects move together in a crystalline order. We will investigate the transport properties of this passive state of active matter in a noisy environment (beyond small perturbations approach). Specifically, we will examine the influence of the strengths and range of interactions into a gradient field in a violently perturbed environment We will examine to which extent collective transport surpasses the performance of an individual motion.

Part II, phase transition of dynamical swarms. When the interactions are modulated the system becomes the active counterpart of a time crystal. We expect that modulating the interactions will triggers a dynamical phase transition towards a Floquet states of active matter. In passive systems, the modulation of interactions triggers a parametric instability which can be understood as a very efficient frequency filter. We aim at leveraging this property into active systems to promote collective robustness of swarms.

Part III, self-learning swarms. The amplitude and frequency as well as the network of interactions between individuals can be tuned as wanted and even dynamically if the environment is changing. Indeed, in programmable active matter, a program can be imbedded on board of each individuals. As a result, the parameter optimization can be achieved autonomously. In that sense the assembly changes its rules of interactions collectively and “self-learns” its environment. Mimicking a reservoir computing, we will examine whether the multiple degree of freedom of the system enables an efficient convergence towards the optimum.

Skills

It is a numerically/theoretically-oriented physics project. Strong skills in programming (preferably C++ or matlab or Python), dynamical systems theory, phase transition and statistical physics is an asset. The Physical-Chemistry Theory group has important local computational resources as well as an access to massive clusters for further intensive computations. An applicant who likes interacting with experimentalists is of course the most welcome. Speaking French is not a requirement at all!

Scientific environment

The candidate will be hosted at Gulliver and supervised by Matthieu Labousse (Gulliver) and cosupervised by Emmanuel Fort (Institut Langevin). Gulliver is a very active and multidisciplinary at ESPCI in the center of Paris. It research fields range from theoretical physical-chemistry, soft matter, molecular programming, statistical physics to microfluidics. Gulliver a strong desire to promote cross-group collaborations and to provide a stimulating environment where talented researchers can interact and work together on a daily basis. The Langevin Institute is a research unit affiliated with ESPCI Paris and CNRS. The researches conducted at the Institute aim at developing at the best world-level the physics of waves bringing together high level fundamental research, applied research, and company start-ups in a thoroughly cross-disciplinary way.

This project aims at combining the strength of the two laboratories in the domains of the statistical physics of active matter and complex systems (Gulliver) and time-crystals and time varying medium (Institut Langevin).

Application procedure

This 3 years project is funded by the European Union (COFUND UptoParis) and applications must be uploaded to https://www.upto.paris/-upTo-paris-.html. The call for applications will start July 15th 2018 and close September 15th 2018. The applications will be reviewed by an external and independent referees panel. The best candidates will be interviewed mid-December 2018. The selected candidate will start in 2019 (typically between April and September 2019).